

Our invisible Sun



Study time: 40 minutes

Summary

In this activity you will view a video sequence that describes how our understanding of solar phenomena has been advanced by making observations across the electromagnetic spectrum, from radio to X-rays. The video sequence refers to concepts relating to electromagnetic radiation that were introduced in Chapter 1 of *An Introduction to the Sun and Stars*, but is primarily concerned with the observation of phenomena that are related to solar activity. This sequence is best watched after you have read to the end of Chapter 2 of *An Introduction to the Sun and Stars*.

Learning outcomes

- Appreciate the importance of multi-wavelength observations in solar astronomy and in astronomy in general.
- Recognize some of the key characteristics of solar flares and coronal mass ejections.

The activity

This activity is based around a long (about 20 minute) video sequence, which was originally shot in 1993. Although there have been advances in observing technology since the video was made the principles behind the observations are still relevant today.

- Start the S282 Multimedia guide and then click on Our invisible Sun under 'The Sun' folder in the left-hand panel.
- Press the **Start** button to run the video sequence.

After you have watched the video sequence read the summary provided in the notes below.

Notes

The video sequence can be summarized as follows.

The sequence begins with a sunrise as seen in X-rays by the satellite Yohkoh. After glimpses of images in ultraviolet radiation it turns to visible images, in particular those made at the Big Bear Solar Observatory (BBSO).

Rather than making brief specialized observations the BBSO has monitored the Sun over many years. Harold Zirin, its founder and director and famous solar astronomer, explains and demonstrates the functions of its three telescopes and detectors, all on the same mounting. The largest has a 26 inch diameter mirror in

an evacuated housing, and was originally made for launch as part of a satellite-borne solar telescope. In fact, very long-term monitoring is of necessity ground-based and therefore confined to the visible and near infrared regions. Despite this restriction a vast amount of experience of the variety and timescales of solar active regions has been gained. In conjunction with a sister observatory in Beijing, China, round-the-clock operation can be achieved. Observations at other wavelengths are correlated with this nearly continuous record.

One of the advantages of the great intensity of light from the Sun is that one can afford to use filters with a very narrow acceptance of wavelengths. Narrow filters are able to isolate the spectral lines of particular chemical elements. The video shows this in action using observations made at the wavelength of the hydrogen alpha ($H\alpha$) line. Images at this wavelength reveal phenomena taking place above the photosphere in the solar atmosphere, including motions (via Doppler shifts) and details of the magnetic field strength. The various images reveal a wealth of phenomena associated with flares, sunspots, and other sorts of activity, in all of which the gas (plasma) in the solar atmosphere interacts with the magnetic field.

To investigate flares further use is made of images at radio wavelengths, as is demonstrated by Mukul Kundu, using images from the Very Large Array in New Mexico. By combining the radio and visible images in a flare region a clear picture is obtained of the way in which a radio flare is generated by electrons spiralling in a magnetic field that arches up from the Sun. The advantage of combining images from different wavelengths was very obvious – this advantage applies throughout astronomy.

The solar atmosphere above the photosphere (i.e. towards the corona) is well seen in ultraviolet radiation. Not only is the temperature different, but, as Ken Phillips showed, the structure is different, showing a type of granulation, but at scales very different from that in the photosphere. Looped structures break through these layers and surge upward towards the corona. The most energetic events are seen in X-ray images.

One effect of the plasma surges may be coronal mass ejections: the ejection of thousands of millions of tons of matter out into the solar wind, and in some cases towards the Earth. Richard Harrison showed how the stream of plasma can be followed by careful recording of radio scintillations, which indirectly yields images of the plasma. If it strikes the top of the Earth's atmosphere, auroral displays are produced. Beyond the Earth the plasma travels on out towards the heliopause, the magnetic boundary between the Solar System and the interstellar medium.

The fundamental nature of flare activity is underlined by the fact that it occurs in other stars. Stuart Bowyer explains a particularly revealing observation of a flare star (AU Mic) by the satellite-borne Extreme Ultraviolet Explorer (EUVE) telescope. We can detect only very large flares in other stars because they are vastly more distant than the Sun. But their existence in turn raises the question of whether such huge flares could ever occur on our Sun. If they did, the huge increase of radiation would probably be fatal for most life-forms on Earth. This raises the art of flare prediction above the level of academic interest!

Video credits

Speakers (in order of appearance)

Harold Zirin (Big Bear Solar Observatory)

Mukul Kundu (University of Maryland)

Ken Phillips (Space Science Group, Rutherford Appleton Laboratory)

Richard Harrison (Space Science Group, Rutherford Appleton Laboratory)

Stuart Bowyer (University of California at Berkeley)

Producer – Tony Jolly (BBC)

Narrator – Veronika Hykes

Course team consultants – Alan Cooper and Bob Lambourne